CLAIMS

1. Apparatus for inspection of a sample, comprising:

a radiation source, which is adapted to direct optical radiation onto an area of a surface of the sample;

a plurality of image sensors, each of which is configured to receive the radiation scattered from the area into a different, respective angular range, so as to form respective images of the area; and

an image processor, which is adapted to process at least one of the respective images so as to detect a defect on the surface.

2. The apparatus according to claim 1, and comprising a single objective, which is configured to capture the radiation scattered from the surface within an aperture that includes the angular range of all the image sensors, and to convey to each of the image sensors the captured radiation in the respective angular range.

3. The apparatus according to claim 2, wherein the objective has a numerical aperture (NA) of at least approximately 0.95.

4. The apparatus according to claim 1, and comprising collection optics, which comprise a plurality of objectives, each of which is respectively associated with one of the image sensors so as to capture the radiation scattered from the surface over the respective angular range, and to convey the captured radiation to the one of the image sensors.

5. The apparatus according to claim 4, wherein the objectives have respective optical axes that intercept the surface at respective oblique angles, and wherein the collection optics further comprise:

a plurality of tilt correction units, which are associated respectively with the objectives and are adapted to correct for the respective oblique angles so as to create substantially undistorted intermediate images; and

a plurality of focusing optics, which are optically coupled to focus the intermediate images onto the image sensors.

6. The apparatus according to claim 5, wherein at least two of the oblique angles are at different, respective elevations relative to the surface, and wherein the tilt correction units are adapted to correct for the different elevations so that the intermediate images are substantially undistorted irrespective of the elevations.

7. The apparatus according to claim 5, wherein the objectives comprise afocal, telecentric relay optics having unit magnification.

8. The apparatus according to claim 4, wherein the collection optics comprise multiple lenses associated with each of the image sensors, and wherein the lenses are selectable so as to vary a magnification of the images formed by the sensor arrays.

9. The apparatus according to claim 1, and comprising a plurality of image intensifiers, each of which is respectively associated with one of the image sensors, so as to receive the radiation scattered from the surface over the respective angular range, and to provide intensified radiation to the one of the image sensors, responsively to the received radiation.

10. The apparatus according to claim 9, wherein the radiation source is adapted to generate pulsed radiation,

and wherein the image intensifiers are gated in synchronization with the pulsed radiation.

11. The apparatus according to claim 9, wherein the radiation received by the image intensifiers has a first frequency, and wherein the image intensifiers are adapted to provide the intensified radiation at a second frequency, lower than the first frequency.

12. The apparatus according to claim 1, and comprising one or more optical filters respectively associated with each of the image sensors so as to filter the radiation received by the arrays, the optical filters comprising at least one of a polarization filter, a wavelength filter and a spatial filter.

13. The apparatus according to claim 12, wherein the optical radiation comprises radiation of a first wavelength, and wherein the scattered radiation comprises fluorescent radiation generated by the sample at a second wavelength responsively to the radiation of the first wavelength, and wherein the wavelength filter is selected so as to permit at least one of the image sensors to capture the fluorescent radiation of the second wavelength while rejecting the radiation of the first wavelength.

14. The apparatus according to claim 1, wherein the radiation source comprises an optical switch, which is adapted to select at least one of a wavelength of the radiation to be directed onto the surface and an incidence angle of the radiation on the surface.

15. The apparatus according to claim 14, wherein the radiation source is adapted to emit radiation in at least first and second wavelength bands, and wherein the optical

switch is adapted to direct the radiation in each of the at least first and second wavelength bands onto the surface.

16. The apparatus according to claim 15, wherein the optical switch is configurable so that the radiation in the first wavelength band is normally incident on the surface, while the radiation in the second wavelength band is obliquely incident on the surface.

17. The apparatus according to claim 14, wherein the radiation source is adapted to emit radiation in at least first and second wavelength bands and further comprises relay optics, which are coupled to direct the radiation onto the surface so that the first and second wavelength bands are incident on the surface at different incidence angles and irradiate the area of the surface with a substantially similar geometrical profile.

18. The apparatus according to claim 1, wherein the radiation source comprises telecentric magnifying optics with a first magnification that is selectable so as to vary a size of the area irradiated by the radiation source, and comprising multiple lenses associated with each of the image sensors, wherein the lenses are selectable to vary a second magnification of the images formed by the sensor arrays responsively to the first magnification.

19. The apparatus according to claim 1, wherein the radiation source is adapted to emit pulsed radiation, and wherein the image sensors are adapted to form the respective images in synchronization with the pulsed radiation.

20. The apparatus according to claim 18, wherein the radiation source comprises:

a pulsed laser, which is adapted to emit the radiation in pulses shorter than 1 μs in duration; and

a speckle-reduction module, which is coupled to de-correlate the radiation so as to reduce a contrast of speckles formed on the area to less than 10%.

21. The apparatus according to claim 20, wherein the speckle-reduction module is adapted to reduce the contrast of the speckles to no more than about 1%.

22. The apparatus according to claim 20, wherein the speckle-reduction module comprises one or more fiberoptic bundles.

23. The apparatus according to claim 20, wherein the speckle-reduction module comprises an opto-electronic transducer, which is coupled to scan an incidence angle of a beam of the radiation over a target plane during each of the pulses so as to de-correlate the radiation.

24. The apparatus according to claim 20, wherein the radiation source comprises a pulsed laser, which is adapted to lase in multiple transverse modes simultaneously, and wherein the speckle-reduction module is adapted to mix the transverse modes in order to reduce the contrast of the speckles.

25. The apparatus according to claim 1, and comprising a scanner, which is adapted to translate one or more of the sample, the radiation source and the image sensors so as to scan the area imaged by the sensor arrays over the surface of the sample.

26. The apparatus according to claim 25, wherein the sample comprises a semiconductor wafer having a pattern of dice formed thereon, and wherein the image sensors are

coupled to operate in synchronization with the scanner, so that the respective images are aligned with the dice.

27. The apparatus according to claim 26, wherein the dice have boundaries, and wherein each of the image sensors comprises multiple rows of detector elements and is configurable so as to select a number of the rows to be used in forming the images so that the images are aligned with the boundaries of the dice.

28. The apparatus according to claim 26, wherein the scanner is adapted to scan the area imaged by the sensor arrays so that the sensor arrays capture first and second respective images of a predetermined area on successive first and second dice along a scan line, and wherein the image processor is adapted to compare the first and second images in order to detect the defect.

29. The apparatus according to claim 1, wherein the image processor comprises:

a plurality of image processing channels, each of which is coupled to process the images formed by a respective one of the sensor arrays and to generate a respective output responsive thereto; and

a multi-perspective processor, which is coupled to process the output from two or more of the image processing channels so as to generate a list of defects on the sample.

30. The apparatus according to claim 29, wherein the multi-perspective processor is adapted to detect the defects by comparing the output from the two or more of the image processing channels.

31. The apparatus according to claim 29, and comprising an energy meter, which is adapted to sense variations in intensity of the radiation emitted by the radiation source,

wherein the image processing channels are adapted to normalize the images responsively to the variations sensed by the energy meter.

32. The apparatus according to claim 29, wherein each of the image processing channels is adapted to correct coordinates of pixels in the images formed by the respective one of the sensor arrays, so as to compensate for optical distortion in the images due to the respective angular range of the scattered radiation.

33. The apparatus according to claim 32, wherein each of the image processing channels is adapted to detect locations of deviations in the images formed by the respective one of the sensor arrays relative to a predefined reference, and to correct the coordinates of the pixels at the locations of the deviations for output to the multi-perspective processor, without correcting the coordinates of at least some other pixels in the images.

34. The apparatus according to claim 29, wherein each of the image processing channels is adapted to detect deviations in the images formed by the respective one of the sensor arrays relative to a predefined reference.

35. The apparatus according to claim 34, wherein the sample comprises a semiconductor wafer having a pattern of dice formed thereon, and wherein the image processing channels are adapted to associate each of the images formed by the respective one of the sensor arrays with a respective location on one of the dice, and to compare each of the images to a reference image formed at the respective location on another one of the dice.

36. A method for inspection of a sample, comprising:

directing optical radiation onto an area of a surface of the sample;

receiving the radiation scattered from the area using a plurality of image sensors so as to form respective images of the area, each of the image sensors being configured to receive the radiation that is scattered to into a different, respective angular range; and

processing at least one of the respective images so as to detect a defect on the surface.

37. The method according to claim 36, wherein receiving the radiation comprises capturing the radiation scattered from the surface using single objective having an aperture that includes the angular range of all the image sensors, and conveying from the single objective to each of the image sensors the captured radiation in the respective angular range.

38. The method according to claim 37, wherein the objective has a numerical aperture (NA) of at least approximately 0.95.

39. The method according to claim 36, wherein receiving the radiation comprises capturing the radiation scattered from the surface using a plurality of objectives, each such objective associated with a respective one of the image sensors so as to capture the radiation scattered from the surface over the respective angular range, and conveying the captured radiation from each of the objectives to the one of the image sensors that is associated therewith.

40. The method according to claim 39, wherein the objectives have respective optical axes that intercept the surface at respective oblique angles, and wherein receiving the radiation further comprise:

correcting for the respective oblique angles using a plurality of tilt correction units, which are associated respectively with the objectives, so as to create substantially undistorted intermediate images; and

focusing the intermediate images onto the image sensors.

41. The method according to claim 40, wherein at least two of the oblique angles are at different, respective elevations relative to the surface, and wherein correcting for the respective oblique angles comprises correcting for the different elevations using the tilt correction units so that the intermediate images are substantially undistorted irrespective of the elevations.

42. The method according to claim 40, wherein capturing the radiation comprises configuring the objectives as afocal, telecentric relays having unit magnification.

43. The method according to claim 39, wherein conveying the captured radiation comprises selecting one of a plurality of lenses so as to vary a magnification of the images formed by the image sensors.

44. The method according to claim 36, wherein receiving the radiation comprises coupling a respective image intensifier to each of the image sensors, and intensifying the radiation received by each of the image sensors using the image intensifier.

45. The method according to claim 44, wherein directing the optical radiation comprises irradiating the sample with pulsed radiation, and wherein intensifying the radiation comprises gating the image intensifiers in synchronization with the pulsed radiation.

46. The method according to claim 44, wherein the radiation received by the image intensifiers has a first frequency, and wherein intensifying the radiation comprises providing the intensified radiation to the image sensors at a second frequency, lower than the first frequency.

47. The method according to claim 36, wherein receiving the radiation comprises applying one or more optical filters to filter the radiation received by each of the image sensors, the optical filters comprising at least one of a polarization filter, a wavelength filter and a spatial filter.

48. The method according to claim 47, wherein the optical radiation comprises radiation of a first wavelength, and wherein the scattered radiation comprises fluorescent radiation generated by the sample at a second wavelength responsively to the radiation of the first wavelength, and wherein applying the one or more optical filters comprises applying the wavelength filter so as to permit at least one of the image sensors to capture the fluorescent radiation of the second wavelength while rejecting the radiation of the first wavelength.

49. The method according to claim 36, wherein directing the optical radiation comprises actuating an optical switch to select at least one of a wavelength of the radiation to be directed onto the surface and an incidence angle of the radiation on the surface.

50. The method according to claim 49, wherein directing the optical radiation comprises generating the radiation in at least first and second wavelength bands, and wherein actuating the optical switch comprises configuring the

switch so as to direct the radiation in each of the at least first and second wavelength bands onto the surface.

51. The method according to claim 50, wherein configuring the switch comprises directing the radiation in the first wavelength band to be normally incident on the surface, while directing the radiation in the second wavelength band to be obliquely incident on the surface.

52. The method according to claim 49, wherein directing the optical radiation comprises generating the radiation in at least first and second wavelength bands, and directing the radiation onto the surface using relay optics, so that the first and second wavelength bands are incident on the surface at different incidence angles and irradiate the area of the surface with a substantially similar geometrical profile.

53. The method according to claim 36, wherein directing the optical radiation comprises setting telecentric magnifying optics to a first magnification that is selectable so as to vary a size of the area irradiated by the radiation source, and wherein receiving the radiation comprises varying a second magnification of the images formed by the sensor arrays responsively to the first magnification.

54. The method according to claim 36, wherein directing the optical radiation comprises irradiating the surface with pulsed radiation, and wherein receiving the radiation comprises synchronizing the image sensors to form the respective images in synchronization with the pulsed radiation.

55. The method according to claim 54, wherein irradiating the surface comprises generating pulses of coherent

radiation shorter than 1 μs in duration, and de-speckling the coherent radiation so as to reduce a contrast of speckles formed on the area due to the coherent radiation to less than 10%.

56. The method according to claim 55, wherein de-speckling the coherent radiation comprises reducing the contrast of the speckles to no more than about 1%.

57. The method according to claim 55, wherein de-speckling the coherent radiation comprises passing the radiation through one or more fiberoptic bundles.

58. The method according to claim 55, wherein de-speckling the coherent radiation comprises opto-electronically scanning an incidence angle of a beam of the radiation over a target plane during each of the pulses so as to de-correlate the radiation.

59. The method according to claim 55, wherein generating the pulses comprises operating a pulsed laser in multiple transverse modes simultaneously, and wherein de-speckling the coherent radiation comprises mixing the transverse modes.

60. The method according to claim 36, and comprising scanning the area imaged by the sensor arrays over the surface of the sample.

61. The method according to claim 60, wherein the sample comprises a semiconductor wafer having a pattern of dice formed thereon, and wherein receiving the radiation comprises operating the image sensors in synchronization with scanning the area, so that the respective images are aligned with the dice.

62. The method according to claim 61, wherein the dice have boundaries, and wherein each of the image sensors comprises multiple rows of detector elements, and wherein operating the image sensors comprises selecting a number of the rows to be used in forming the images so that the images are aligned with the boundaries of the dice.

63. The method according to claim 61, wherein scanning the area comprises capturing first and second respective images of a predetermined area on successive first and second dice along a scan line, and wherein processing the at least one of the respective images comprises comparing the first and second images in order to detect the defect.

64. The method according to claim 36, wherein comparing the images comprises processing the images formed by the sensor arrays in respective image processing channels, so as to generate respective outputs, and combining the outputs from two or more of the image processing channels so as to generate a list of defects on the sample.

65. The method according to claim 64, wherein combining the outputs comprises comparing the outputs from the two or more of the image processing channels in order to detect the defects.

66. The method according to claim 64, wherein processing the images comprises sensing variations in intensity of the radiation directed onto the area, and normalizing the images responsively to the variations.

67. The method according to claim 64, wherein processing the images comprises correcting coordinates of pixels in the images formed by each of the sensor arrays, so as to compensate for optical distortion in the images due to the respective angular range of the scattered radiation.

68. The method according to claim 67, wherein processing the images comprises detecting, in the respective image processing channels, locations of deviations in the images formed by the sensor arrays relative to a predefined reference, and correcting the coordinates of the pixels at the locations of the deviations for use in combining the outputs to generate the list of defects, without correcting the coordinates of at least some other pixels in the images.

69. The method according to claim 64, wherein processing the images comprises detecting, in the respective image processing channels, deviations in the images formed by the sensor arrays relative to a predefined reference.

70. The method according to claim 69, wherein the sample comprises a semiconductor wafer having a pattern of dice formed thereon, and wherein detecting the deviations comprises associating each of the images formed by each of the sensor arrays with a respective location on one of the dice, and comparing each of the images to a reference image formed at the respective location on another one of the dice.